# United States Patent [19]

**Manger et al.**

[11] **4,112,890**

[45] **Sep. 12, 1978**


[54] **CONTROLLED IGNITION SYSTEM FOR AN INTERNAL COMBUSTION ENGINE TO PROVIDE, SELECTIVELY, ONE OR MORE IGNITION PULSES FOR ANY IGNITION EVENT**


[75] Inventors: **Hansjörg Manger**, Schwieberdingen; **Gerhard Söhner**, Remshalden; **Gerd Hohne**, Ludwigsburg, all of Fed. Rep. of Germany

[73] Assignee: **Robert Bosch GmbH**, Stuttgart, Fed. Rep. of Germany



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[30] **Foreign Application Priority Data**

Apr. 15, 1976 [DE] Fed. Rep. of Germany ....... 2616693

[51] **Int. Cl.**[2] ................................................ **F02P 5/04**

[52] **U.S. Cl.** ............................ **123/117 R**; 123/148 E

[58] **Field of Search** ........... 123/148 E, 117 R, 149 C, 123/119 A



[56] **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,853,103 | 12/1974 | Wahl et al. ...................... | 123/117 R |
| 3,881,458 | 5/1975 | Roozenbook et al. .......... | 123/148 E |
| 3,923,021 | 12/1975 | Stark ............................... | 123/117 R |
| 3,923,022 | 12/1975 | Scholl ............................. | 123/148 E |



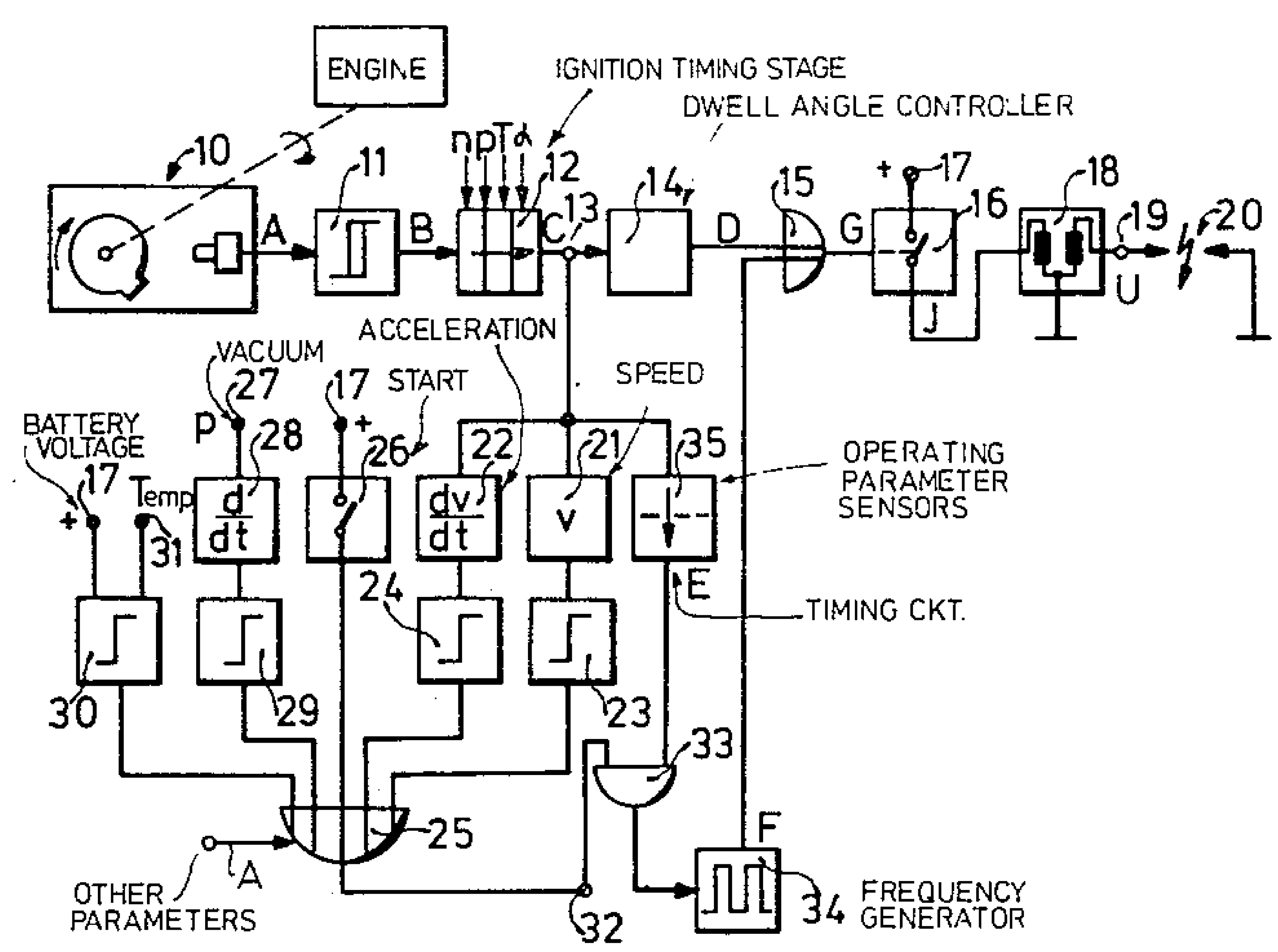
*Primary Examiner*—Charles J. Myhre
*Assistant Examiner*—Raymond A. Nelli
*Attorney, Agent, or Firm*—Flynn & Frishauf



[57] **ABSTRACT**

To provide a first accurately timed ignition impulse for any one ignition event, and then, selectively, one or more ignition pulses, in accordance with sensed or existing operating parameters of the engine, a first ignition pulse is generated, accurately, in accordance with timing as determined by an ignition timing stage; a frequency generator is selectively enabled upon the presence or absence of operating parameters at certain values to provide sequential ignition pulses after the first, accurately timed ignition pulse has been provided.


**17 Claims, 4 Drawing Figures**



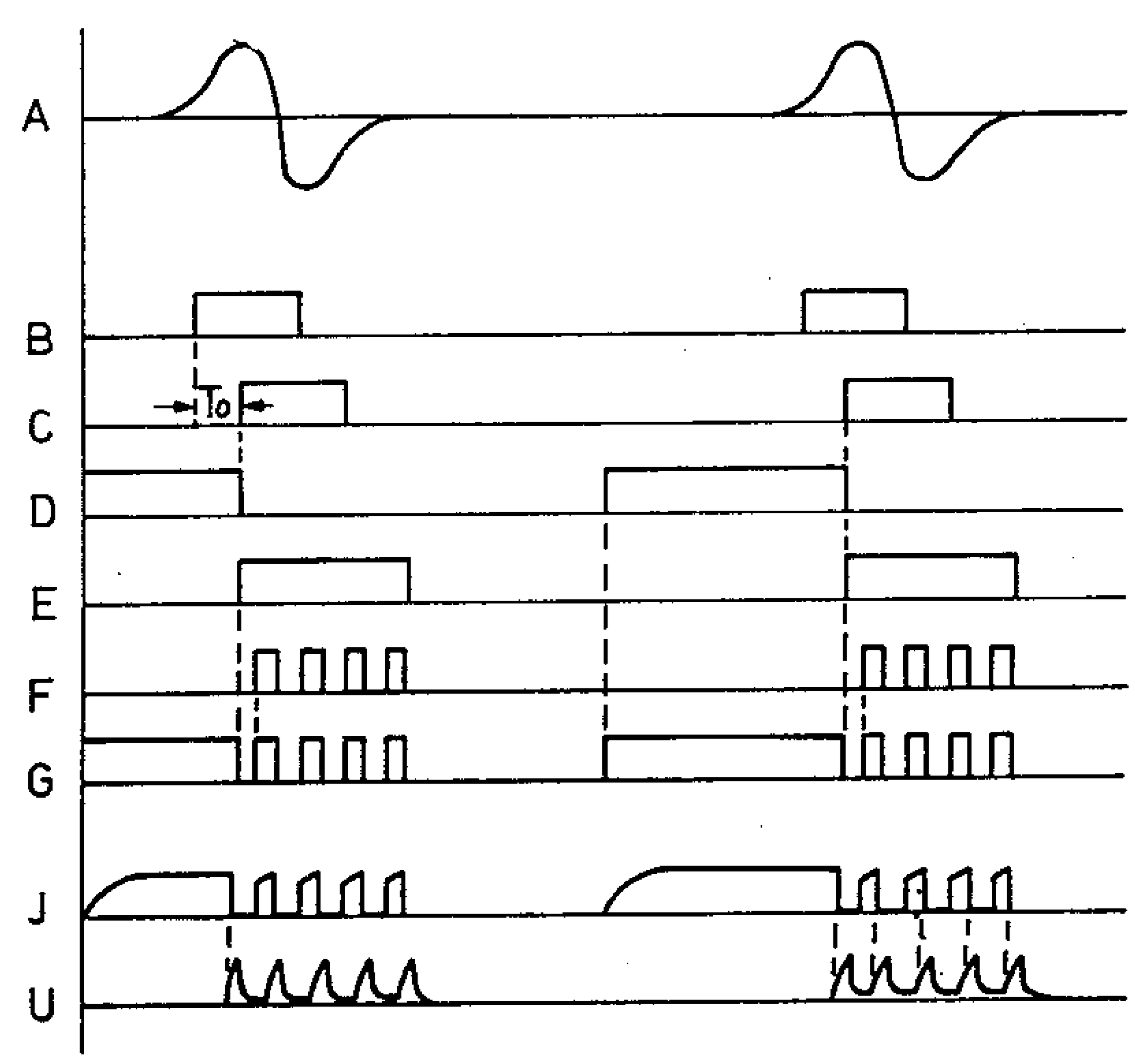



Fig.1

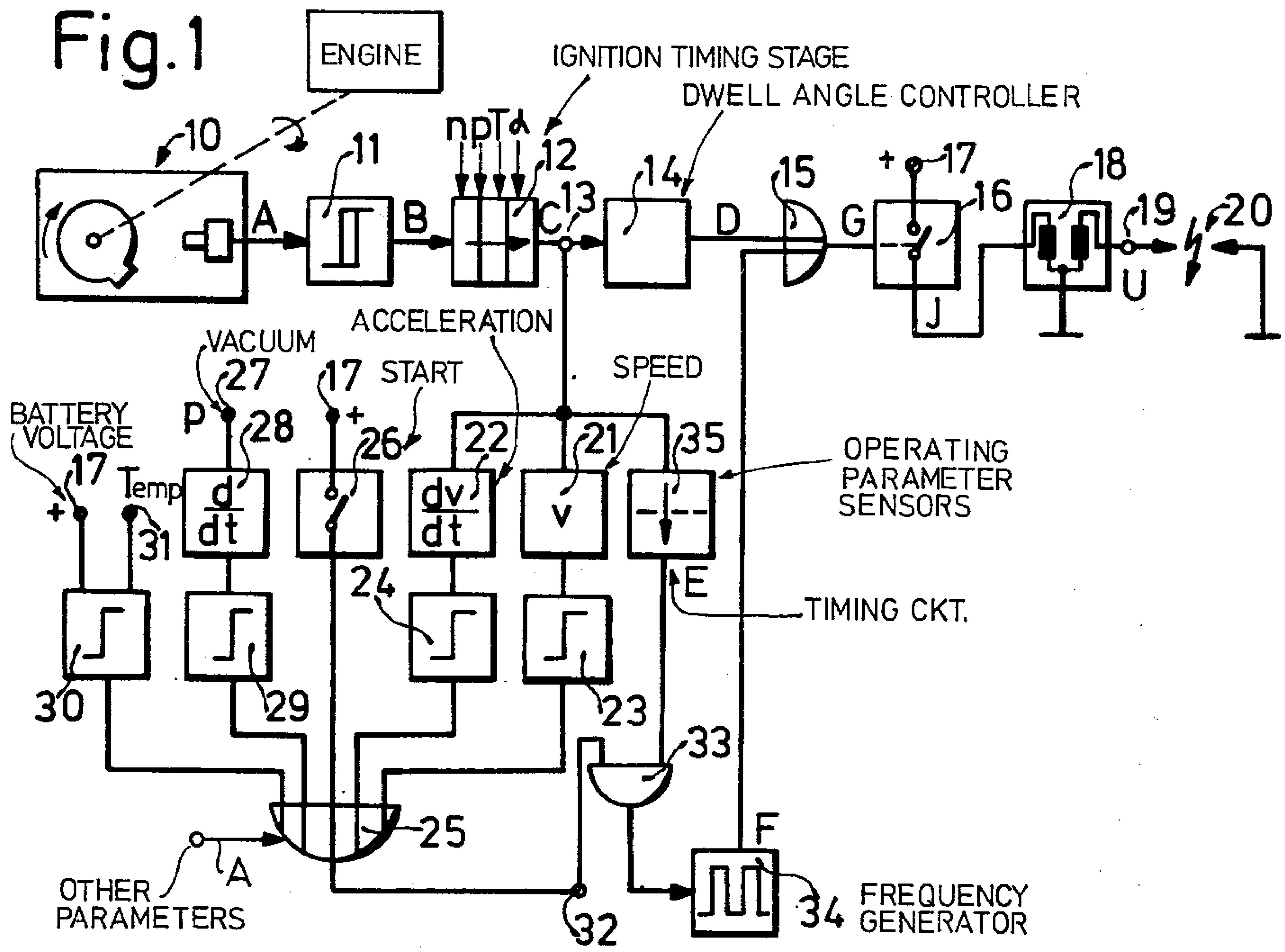

ENGINE
IGNITION TIMING STAGE
DWELL ANGLE CONTROLLER
10
11
12
13
14
15
16
17
18
19
20
A
B
C
D
G
J
U
n p T α
VACUUM
ACCELERATION
START
SPEED
BATTERY VOLTAGE
P
27
28
17
26
22
21
35
Temp
31
d/dt
dv/dt
v
OPERATING PARAMETER SENSORS
24
E
TIMING CKT.
30
29
23
33
25
F
OTHER PARAMETERS
32
34
FREQUENCY GENERATOR

Fig.2

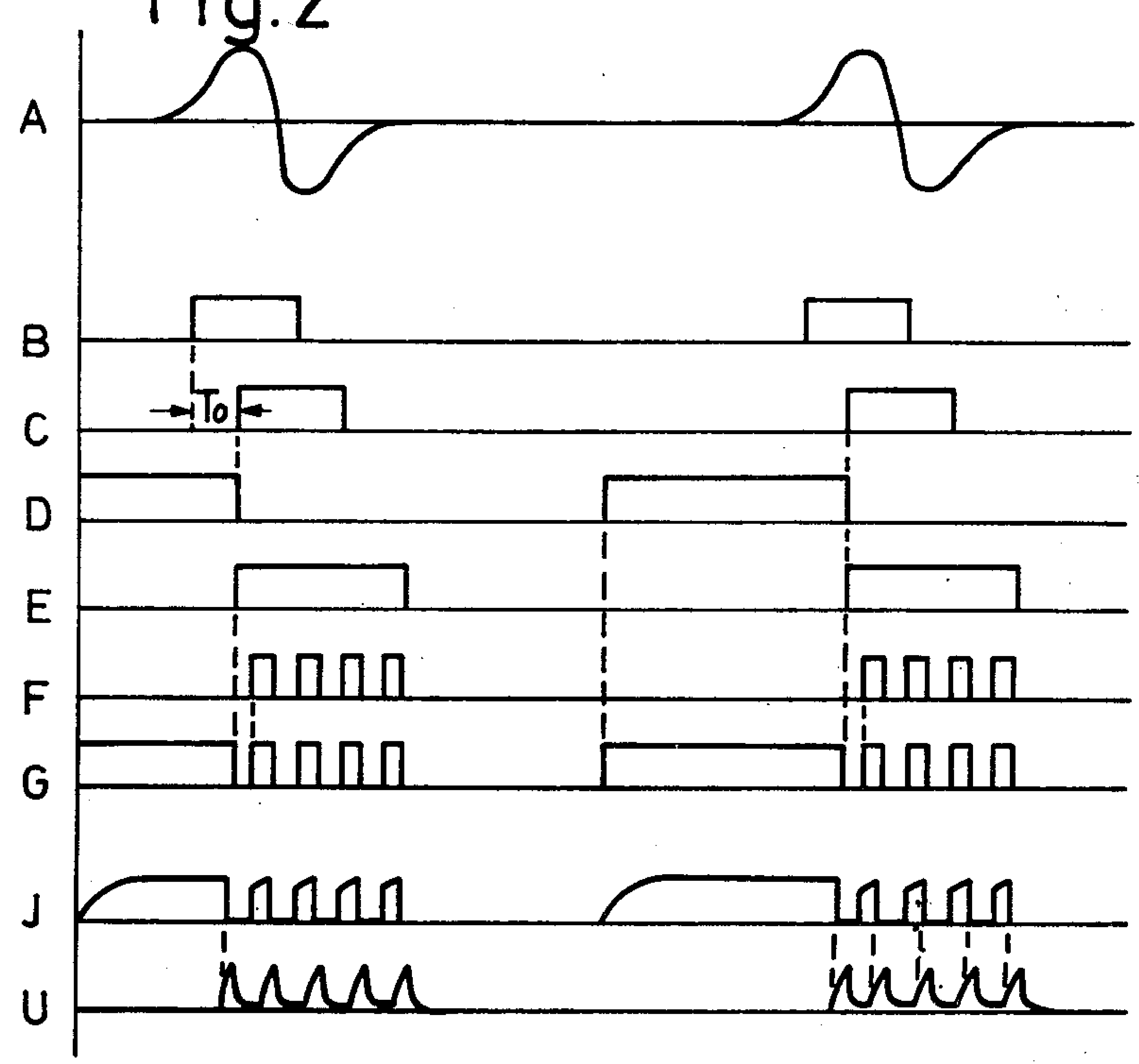

A
B
C
D
E
F
G
J
U
To

Fig. 3

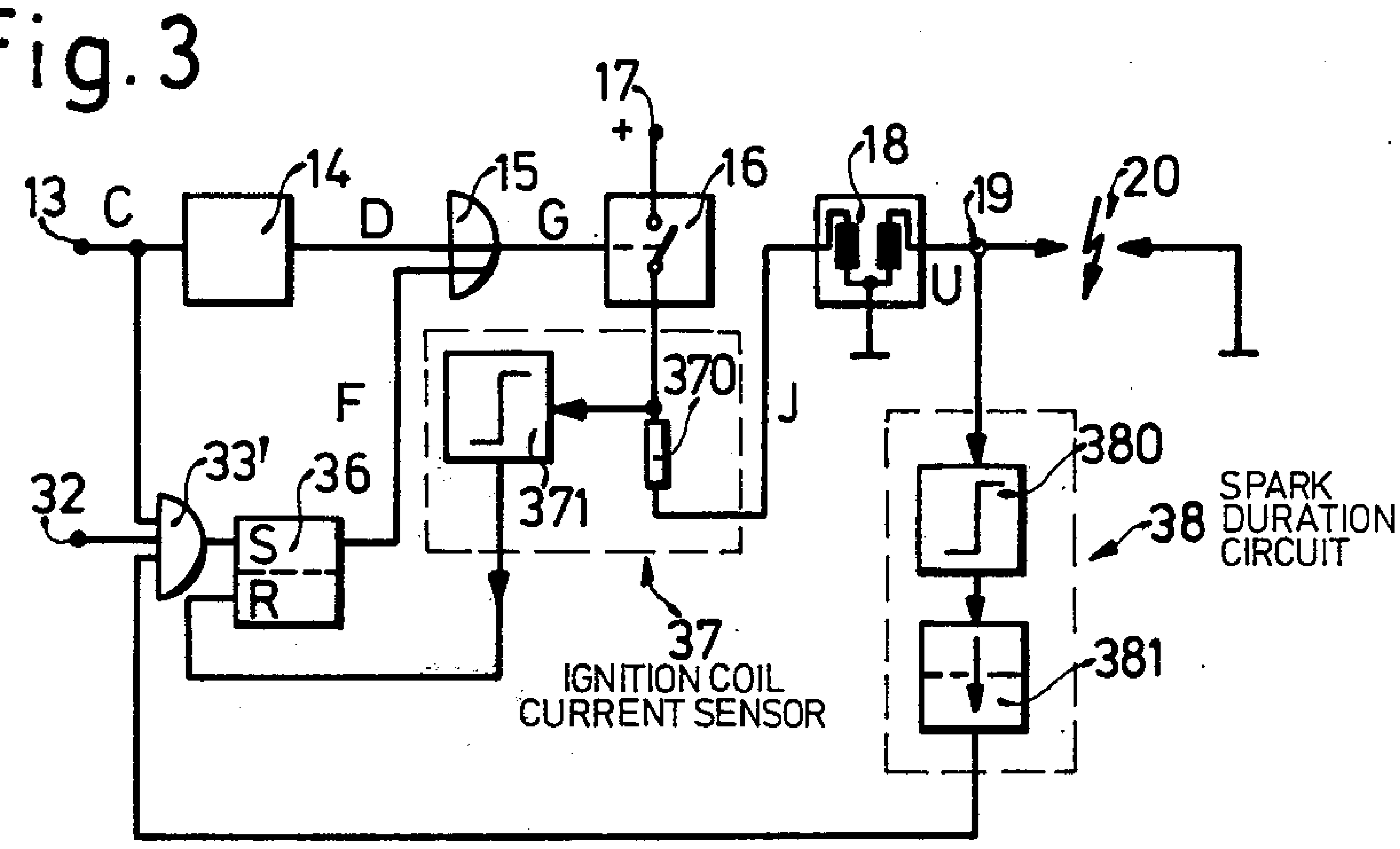
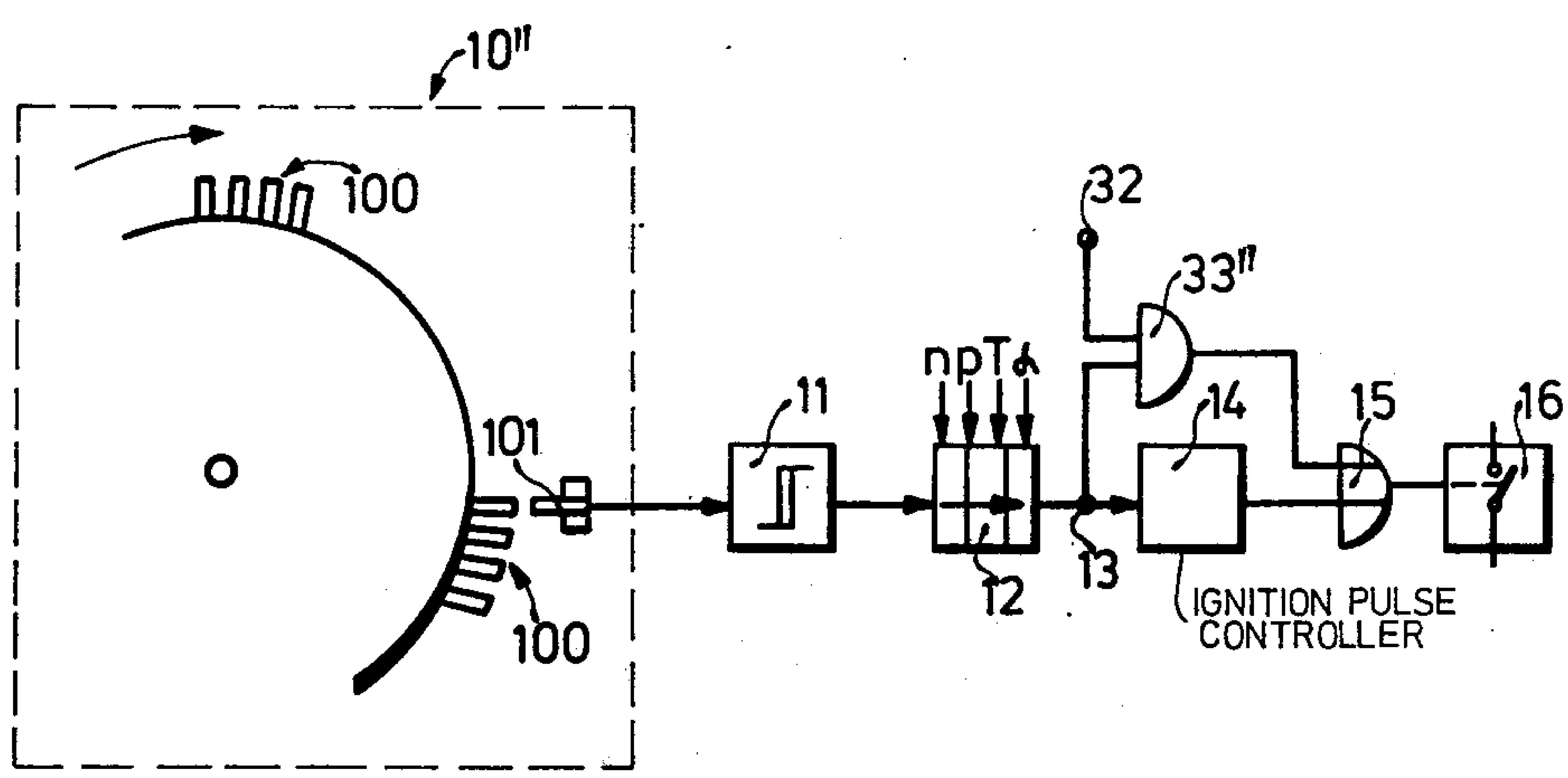

17
+
13
C
14
D
15
G
16
18
19
20
U
F
370
J
33'
36
32
S
R
371
380
SPARK
DURATION
CIRCUIT
38
37
IGNITION COIL
CURRENT SENSOR
381

Fig. 4


10''
100
101
100
11
npTϑ
12
13
32
33''
14
15
16
IGNITION PULSE
CONTROLLER

# CONTROLLED IGNITION SYSTEM FOR AN INTERNAL COMBUSTION ENGINE TO PROVIDE, SELECTIVELY, ONE OR MORE IGNITION PULSES FOR ANY IGNITION EVENT

Cross reference to related applications and patent:
U.S. Ser. No. 776,739, filed Mar. 11, 1977 Rabus et al;
U.S. Ser. No. 776,735, filed Mar. 11, 1977, Grather et al;
U.S. Ser. No. 776,738, filed Mar. 11, 1977, Rabus et al;
U.S. Pat. No. 3,881,458;
all assigned to the assignee of the present application.

The present invention relates to an ignition system for internal combustion engines, and more particularly to an ignition system for an automotive-type internal combustion engine in which operating and environmental parameters of the condition of the engine, and its operation, can be considered.

## BACKGROUND AND PRIOR ART

In ignition systems of the type to which the present invention relates, an ignition coil has a controlled switch connected in the primary circuit thereof, the secondary being connected to one or more spark plugs, preferably through a distributor. An ignition control element, for example an inductive transducer, controls the operation of the controlled switch to pass current therethrough and charge the ignition coil. The controlled switch is closed at a predetermined instant of time, causing rapid rise of current through the ignition coil which will terminate in a saturation current if the switch remains closed for a long enough period of time. Upon opening of the switch, the secondary voltage provides a pronounced voltage kick which has a high enough voltage to cause breakdown of the spark gap of the spark plug if the ignition system is connected to an internal combustion engine, for example of the automotive type. The transducer provides an ignition signal at a predetermined time with respect to an operating state of the internal combustion (IC) engine, for example with respect to the upper dead center (UDC) position of a piston thereof. Suitable ignition timing circuits or other arrangements can be used to shift the ignition signal to provide for advance or retard of the spark with respect to the UDC position of the piston in accordance with various operating or environmental parameters of the internal combustion engine. The ignition timing signal not only controls closing of the switch but primarily controls opening thereof at a predetermined timing instant. A dwell angle control arrangement is provided to close the switch at a proper time so that sufficient current can flow through the coil to store magnetic energy therein, so that the coil will be essentially in saturation and provide, at the proper ignition instant, the full magnetic energy to the spark gap, typically a spark plug. Dwell angle control systems have been previously described, see, for example, the cross-referenced U.S. Pat. No. 3,881,458 (to which German Disclosure Document DT-OS 2,244,781 corresponds). Such ignition systems have a disadvantage, however, in that it is possible that the spark may be too weak or too short, resulting in insufficient or incomplete combustion of the fuel-air mixture in the IC engine. In the limiting case, a misfire may occur, resulting in no combustion of the mixture at that time at all.

It has been proposed to ensure ignition of the fuel-air mixture in the respective cylinder by providing a spark



train, that is, a plurality of firings for each ignition event, occurring rapidly, one after the other. Sequential ignition pulses are generated by enabling a frequency generating to provide a pulse train to a control switch connected to the spark plug, at any ignition event, or with respect to any ignition instant, so that the coil will then provide a pulse train to the spark plug. This system has a disadvantage in that the frequency generator will provide control for the coil of the spark plug only after the ignition instant. Thus, the switch must first close to store magnetic energy in the ignition coil so that, upon subsequent opening, a spark impulse is delivered therefrom to the spark plug. The first firing or arc-over of the spark plug thus occurs at a period of time which is delayed with respect to the actually desired ignition instant.

## THE INVENTION

It is an object to provide an ignition system which provides a spark train or a pulse train to cause a plurality of firings for any ignition event and which further is so arranged that the first firing or arc-over at a spark plug occurs exactly at a predetermined ignition instant. Additionally, the system should be capable of selectively providing either one, or more spark pulses to the spark plug, as determined by operating conditions or parameters of operation of the engine.

Briefly, the ignition pulse control stage is connected to, and controls operation of a switch which commands current flow through the ignition coil at a predetermined time after the occurrence of a preceding ignition event, and in advance of the next subsequent ignition event, to ensure that the coil will reach saturation; the ignition pulse control stage additionally control opening of the switch as determined by the timing of the first, or the only ignition pulse for the next subsequent ignition event, with respect to the UDC position of the respective piston. Frequency generator means are also provided to generate a plurality of ignition pulses, and likewise connected to the ignition coil interrupter switch, to control repetitive opening and closing thereof after the first closing and opening, or change of state of the switch as commanded directly by the ignition pulse control stage. The frequency generator operates at a rate which is rapid with respect to the recurrence rate of ignition events; the frequency generator is selectively connected to the interrupter switch in dependence on the presence or magnitude of operating conditions or parameters rendering desirable the use of multiple ignition sparks in the form of trains of spark plug firings.

The frequency generator, preferably, is enabled only when at least one of the various operating parameters undesirably affecting ignition is present. Such typical operating parameters are battery voltage level, temperature, whether the engine is under starting condition, vacuum in the induction pipe of the engine, whether the engine is then accelerating, its speed, incompleteness of combustion, and the like.

The system ensures reliable and uniform ignition since, first, a spark is generated at the proper ignition instant and, then, a plurality of spark trains may follow, if needed. To protect the spark plug, however, and other circuit elements of the ignition systems, a spark train may not be needed and can thus be disconnected unless the operating conditions of the system indicate that it would be desirable to provide such a spark train.

## DRAWINGS

Illustrating an example:

FIG. 1 shows, in schematic block diagram form, an embodiment of the invention in an ignition system using a frequency generator;

FIG. 2 shows, in sequential graphs, the signals arising in the ignition system;

FIG. 3 is a fragmentary diagram of the ignition system illustrating in detail a circuit arrangement to generate a spark pulse train; and

FIG. 4 is another embodiment, and using a specially designed pulse transducer to generate a plurality of spark signals and controlling operation of the system.

The crankshaft of an internal combustion engine E (FIG. 1) is coupled to a transducer **10** which provides pulsed output signals occurring at a predetermined time or position of a piston in the cylinder, with respect to the upper dead center (UDC) position of the piston, for example. The output from transducer **10** is applied through a wave-shaping circuit **11**, preferably a Schmitt trigger. Transducer **10** is preferably an inductive transducer, but may have other forms, for example a breaker contact, a Hall generator, an optocoupler, or the like. The output of the wave-shaping stage **11** is connected through an ignition timing stage **12** to its output terminal **13** which, in turn, is connected to a dwell angle controller **14**. The ignition timing stage **12** shifts the ignition signal derived from wave-shaping stage **11** in dependence on motor parameters to provide for proper ignition under the then existing operating conditions. Typical motor parameters are engine speed ($n$), induction pipe pressure or, rather, vacuum ($p$), temperature (T) and deflection angle ($\alpha$) of the throttle; other parameters may also be introduced. Such ignition timing stages are well known and need not be described in detail. The dwell angle controller **14** is also known and described, for example, in the cross-referenced U.S. Pat. No. 3,881,458. The output of the dwell angle controller **14** is connected through an OR-gate **15** with the control input of an electrical interrupter switch **16**. Switch **16** preferably is a controlled semiconductor, typically a transistor. It is connected with one terminal of its main current carrying path to a positive supply terminal **17**, for example the battery of a vehicle in which the IC engine E is included. The other terminal of switch **16** is connected to the primary of an ignition coil **18**, the secondary of which is connected through its output terminal **19** with a spark gap **20**, for example a spark plug. The second terminal of the coil **18** as well as of the spark plug is connected to ground or chassis. The spark gap, for use with an internal combustion engine, is usually a spark plug and, for multi-cylinder engines, a distributor is interposed between the output terminal **19** and the various spark plugs of the engine.

In accordance with the present invention, various operating parameters can be used to control opening and closing of the switch **16**, selectively; to this end, terminal **13** is connected to a group of control circuits which, selectively, enable a frequency generator **34**. Terminal **13**, the output of the ignition timing stage **12**, is connected to a circuit which includes, in parallel, a speed measuring stage **21**, an acceleration measuring stage **22**, and a timing circuit **35**. The outputs of the acceleration stage **22** and of the speed stage **21** are connected to threshold circuits **24**, **23**, respectively, the outputs of which are connected to inputs of an OR-gate **25**. Speed sensors are well known in the automotive electronics field; acceleration sensors are also known, and are used, for example, in combination with wheel brake anti-block systems. Essentially, an acceleration sensor is a speed sensing circuit with a differentiating stage connected to its output.

A terminal of a starting switch **26**, which is further connected to the positive terminal **17** forming the power supply, is also connected to a further input of the OR-gate **25**. OR-gate **25** can have other operating parameters for example in the form of threshold signals applied thereto. Terminal **27** is connected to a pressure switch — not shown — and located in the induction pipe of the IC engine E to measure the vacuum in the induction pipe thereof, that is, the pressure $p$. The terminal **28** is connected to a differentiating stage **28**, the output of which is connected to a threshold circuit **29** which, in turn, is connected to the OR-gate **25**. Change in pressure of the induction pipe of the IC engine E results in a differentiated output signal from differentiating stage **28**. If the change in pressure exceeds the threshold limit of switch **29**, threshold stage **29** will change and provide an output signal to OR-gate **25**.

A threshold stage **30** is connected to OR-gate **25**, the input of which is connected to terminal **17** to form a sensing input for battery voltage; another input of threshold switch **30** is connected to a temperature sensor, preferably in temperature sensing relationship with the IC engine E. A signal is derived from threshold switch **30** when either the temperature T or the battery voltage drops below a predetermined value.

The output of the OR-gate **25** is connected to a terminal **32** which forms one input of an AND-gate **33**. AND-gate **33** has its output connected to frequency generator **34**. Frequency generator **34** provides square wave pulses if its input is enabled by the AND-gate **33**. The second input to AND-gate **33** is derived from timing circuit **35**, connected to the terminal **13**. Timing circuit **35**, preferably, is a monostable circuit. The output from frequency generator **34** is connected to the second input of OR-gate **15**.

Operation, with reference to FIG. 2: The signal of graph A from transducer **10** is converted into square wave signals B in the wave-shaping stage **11**. The graph letter indications are also shown in FIG. **1** to illustrate where the respective signals arise. The ignition timing stage **12** shifts the signal B by a time T$o$, in accordance with the ignition timing — engine operating characteristics in view of the input parameters to the timing stage **12**. The output signal C will appear at terminal **13**. The dwell angle controller **14** so changes the signal C that the start of a C signal, which is simultaneously the ignition instant, corresponds to the end of a preceding signal in the dwell angle controller. Thus, the output signal D terminates at the beginning of the ignition impulse, as timed by the ignition timing stage **12**. The beginning of the signal D supplied by the dwell angle controller **14** is determined by the preceding C signal in such a manner that the length of the signal, or the duration of the signal D, is sufficient to provide enough primary current to the ignition coil **18** to bring coil **18** into saturation.

The rising flank of the signal of graph C also controls starting of the timing interval of timing circuit **35**. The output signal of timing circuit **35** is shown on graph E of FIG. 2. If terminal **32** has a signal applied thereto — as will be explained below — frequency generator **34** is enabled during the time of the timing circuit **35** to provide the pulse sequence of the graph F. OR-gate **15** passes the signal of graph D as well as the signal of graph F, so that the interrupter switch **16** is sequentially opened and closed by the composite signals as seen in graph G. The longer signal G, which is also part of the signal D, first closes switch **16**, permitting the current I through coil **18** to rise and certainly reach saturation. At the end of signal D, that is, at the ignition instant, switch **16** will open generating an ignition pulse U across spark plug **19**. The subsequent signal of the signal train F causes closing of the switch **16**, permitting the current through the coil to rise. This current is shown in graph J. Upon termination of the signal of graph F, interrupter switch **16** causing a new ignition pulse, and hence arc-over of the spark plug **20**. This pulse occurs at the same ignition event, that is, in a multi-cylinder engine will be at the same spark plug as that of the first pulse caused by the termination of the signal D. Subsequent signals of the pulse train F, and part of the signal G passed by OR-gate **15**, again cause closing of the switch, rise of current through coil **19** and, upon subsequent opening, a renewed spark pulse across the spark plug. This cycle will repeat in dependence on the number of signals from frequency generator F. If the signals of generator F are very close together, as illustrated in the diagram, it may occur that the magnetic energy in coil **18** is not completely transformed into electrical energy at each ignition spark. Upon the next subsequent closing of switch **16**, current through the coil thus will not rise from a zero value but rather will start at an increased value. Time to saturation of the coil will decrease. As a consequence, the frequency of the pulses of the pulse rain causing repetitive sparking can be selected to be high, and substantially higher than the repetition recurrence of the signals B or C, and hence of the signals D.

The frequency generator **34** is controlled to operate, or not, depending on the signals at AND-gate **33**. This signal is controlled not only by the timing circuit **35**, which determines the length of the signals during which the frequency generator **34** will be effective, but also by the presence of a signal at terminal **32**. Terminal **32**, therefore, determines whether a single spark is to be generated, derived from termination of the signal D, or whether multiple signals should be provided resulting in a spark train. If, in any event, a spark train should occur, the AND-gate **33** can be omitted and the output of timing circuit **35** can be directly connected to the input of the frequency generator **34**. The elements **21, 22, 26, 28, 30**, and associated threshold circuits then can be omitted. In accordance with a feature of the invention, however, a train of ignition pulses, and hence a train of sparks, is provided only if certain operating conditions pertain: Terminals **17** and **31**, having representative values of vehicle battery voltage and engine temperature applied thereto, have signals thereat indicative of a certain low temperature, or supply voltage below a minimum value; terminal **27**, having the vacuum applied thereto, through the differentiator provides a signal that the induction pipe vacuum had a predetermined rate of change with respect to time; starting switch **26** is operated; or speed, or acceleration were above certain limiting upper, or lower values.

All the threshold stages **23, 24, 29, 30** may have an upper and a lower threshold value, so that trains of spark pulses for spark trains are provided within certain operating ranges of the respective parameter, for example below a certain limiting value and above a certain limiting value, indicating, in either case, extremes of operating conditions.

If it is not desired to control operation of the frequency generator with any one of the parameters indicated in FIG. **1**, then the respective element and the associated threshold switch, if used, can be omitted. Other parameters may also be introduced, and such additional operating-dependent parameters are schematically indicated by arrow A, to introduce further inputs, directly or through a threshold stage, to provide an output at terminal **32** and hence enable the AND-gate **33**. One such parameter may, for example, be sensed composition of exhaust gases.

Embodiment of FIG. **3**: Only those elements which differ from the ones previously described will be explained in detail; similar reference numerals to those of FIG. **1** have been used.

Terminal **13** is directly connected to the input of AND-gate **33'**, which has three inputs. AND-gate **33'** has its output connected to the SET input S of a flip-flop (FF) **36**. The output of FF **36** is connected to the second input of the OR-gate **15**. An ignition current sensor **37** is connected serially with the primary of the ignition coil **18**, as shown between the interrupter switch **16** and the ignition coil **18**. Ignition coil current sensor **37** provides an output voltage representative of the current I through the primary of the ignition coil **18**. In its simplest form, it is a resistor **370** connected to apply a voltage representative of current flow through the resistor **370** to an input of a threshold stage **371**. The output of the threshold stage **371** is connected to the RESET input R of FF **36**. Terminal **19**, the output of the secondary of coil **18**, is connected to a spark duration sensor **38**. The output of the spark duration sensor **38** is connected to a further input of the AND-gate **33**. The spark duration sensor **38**, in its simplest form, is a threshold stage **380** which provides a signal when an ignition signal commences and is connected to a subsequent timing circuit **381** which can be so set that a predetermined time duration for the spark train can be set therein.

Operation of circuit of FIG. **3**: The first closing-opening cycle of switch **16** occurs, as described in connection with FIG. **1**, under control of the signal of graph D. Upon termination of the D signal, voltage will rise at terminal **19**. The voltage rise is sensed by the spark duration circuit **38** and threshold circuit **380** will respond, causing the timing circuit **381** to start and provide a timing signal. At the end of the timing interval, as set by the timing circuit **381**, AND-gate **33** is enabled, thus placing the FF **36** into the SET mode, since a C signal is simultaneously present. Terminal **32**, if provided, must also have a signal appear thereat. The signal from terminal **32** can be provided, as described in connection with FIG. **1**. The SET state of the FF **36** results in renewed closing of switch **16**. Current I begins to rise and when it reaches a predetermined threshold, as determined by the stage **371**, FF **36** is reset over the R input. Switch **16** thus is opened, and ignition voltage U again begins to rise. This cycle will repeat until the C signal terminates, that is, provided a signal is applied at terminal **32** (if provided). The duration of the spark train of the system of the embodiment of FIG. **3** is thus not fixed with a respect to a predetermined time — the unstable time of timing circuit **35** in FIG. **1** — but rather is governed by the duration of the output signal from the transducer, as wave shaped and transformed into the signal of graph C (FIG. **2**). The duration of the signal C depends on the width of the signal A. The amplitude of this signal changes with speed, but its width is essentially constant and corresponds to a predetermined angle of rotation of the shaft of the transducer **10**, and hence of the crankshaft of the engine E. Other transducers can be used which provide a signal different from one which is constant with respect to a certain angular displacement of the crankshaft of the engine. Such different transducers would, for example, be sensors to sense when the output voltage goes through null or zero, rate-of-change circuits which sense peaks and change of slope of the signal from the sensors, or slope detectors. Such circuits may use, for example, differentiating stages.

The duration of the extended spark train can also be controlled by a signal which has a predetermined set time period, for example by a timing circuit similar to timing circuit **35** which would then be included in the circuit resetting the FF **36**. Similarly, a spark duration circuit like circuit **38** and an ignition coil current sensing circuit like circuit **37** may be used in connection with the system of FIG. **1**.

Embodiment of FIG. **4**: The transducer **10**″ has a plurality of markers for each ignition event, associated with any one cylinder or piston of the engine, rather than a single marker as illustrated in FIG. **1**. Usually, the markers on the transducer are offset by a crankshaft angle which depends on the number of cylinders; for a four-cylinder engine, these markers are offset with respect to each other by 90°. The transducer **10**″ (FIG. **4**) has a plurality of closely adjacent markers **100**; FIG. **4** illustrates four such markers **100**, for example corresponding to four projections, or other magnetic discontinuities at the circumference of a rotating disk which may be part of, or coupled to the flywheel of the engine. The fixed portion of the transducer, forming a coil pick-up and schematically shown at **101**, then will have four rapidly sequentially occurring pulses at its output. Four pulses similar to the signals A of FIG. 2 will therefore be provided. The stages **11** and **12** thus will provide, in each instant, four D and C signals, each one offset with respect to the signal B by the time *To*. The first C signal at terminal **13** controls the dwell angle controller **14**, as explained in connection with FIG. **1**. The output thereof will be the D signal. The output of the dwell angle control stage **14** is connected over the OR-gate **15** with the control input of the interrupter switch **16**, as in FIG. **1**. Terminal **13**, additionally, is connected over an AND-gate **33**″ with the second input of the OR-gate **15**. The second input of the AND-gate **33**″, as above described, is connected to terminal **32** (if provided). If no signal is applied at terminal **32**, the output signal D of the dwell angle controller will provide a single spark, as described. If, however, terminal **32** is enabled, AND-gate **33** will pass sequential signals and thus the multiple C signals will be transferred from terminal **13** through the OR-gate **15**. The end of the signal D, therefore, will have four signals following the D signal, resulting, overall, in five spark pulses, and five rapidly sequentially following sparks for any ignition event. The first spark, as above described, will occur upon the termination of the D signal, resulting from current flow due to the last preceding spark.

The duration of the spark train is determined by the number and the circumferential placement of the markers **100**.

Collision between the control of the terminal end or trailing flank of the signal D and the start of the first C signal can be improved by connecting a time delay circuit between the terminal **13** and the connecting line from terminal **13** to the input of the AND-gate **33**″. Such a delay circuit prevents coincident timing of the trailing flank or end of the signal D with the start of the first C signal. Other possibilities are open to prevent such interference, and various solutions suggest themselves, such as a coincidence circuit which, if coincidence is detected, delays transfer of one signal from input to output — in this case the signal through AND-gate **33**″. Terminal **32** is controlled as described in connection with FIG. **1**.

Various changes and modifications may be made and features described in connection with any one of the embodiments may be used with any of the others, within the scope of the inventive concept.

In the embodiment of FIG. **4**, the pulses C (FIG. **2**) will be much shorter than those shown in connection with the embodiments of FIGS. **1** and **3**. Yet, because of the short-circuiting of element **14** if gate **33**″ is enabled, the circuit **14** will respond but once. Commencement of current flow through the ignition pulse controller **14**, as determined by the beginning of the D pulse can be controlled, inherently, from the next preceding pulse emitted by the ignition pulse controller **14** itself, that is, regardless of whether ignition pulse controller **14** had only one pulse applied, as in the embodiments of FIGS. **1** and **3**, or sequential pulses were short-circuited therearound by the closed gate **33**″ after the first pulse had been passed by controller **14**.

We claim:

**1**. Ignition system to provide, selectively, one ignition impulse, or a series of ignition pulses to a spark gap **(20)** in which the one, or the first one of said pulses occurs at a predetermined time after occurrence of a cyclically recurring event,

particularly to provide said pulses to the spark plug of an internal combustion engine (E) with respect to a predetermined angular position of the crankshaft of the engine and having

an ignition coil **(18)**, and a spark gap **(20)** connected to the secondary of the ignition coil;

means **(10, 11, 12; 10″)** determining the timing of the event;

and a controlled switch **(16)** in series with a source of current **(17)** and the primary of the ignition coil **(18)** to periodically supply current to the coil and generate said ignition pulse by transformer action, and comprising

an ignition pulse control stage **(14)** connected to and controlling operation of the controlled switch **(16)** to command closing of the switch at a predetermined time after occurrence of the preceding event, and in advance of the next subsequent event, and to command generation of said one, or first one of said ignition pulses as determined by the timing of the next subsequent event;

and means **(34; 100, 101)** generating a plurality of ignition pulses connected to said controlled switch **(16)** and controlling said switch to repetitive operation and cause, after occurrence of said event and at a rate which is rapid with respect to the recurrence rate of said events, to provide a pulse train for generation of a train of sparks at said spark gap, the timing of the first one of said ignition pulses being determined by said ignition pulse control stage;

and means **(32; 33, 33′, 33″)** selectively controlling application of the plurality of ignition pulses, in excess of said first pulse to said spark gap **(20)**.

2. System according to claim 1, wherein (FIG. 1) the pulse generation means (34) has an output connected to the input of said controlled switch (16).

3. System according to claim 1, wherein (FIG. 3) the pulse generation means comprises a controlled switching circuit (36) having two inputs (R, S) controlling the switching state of said controlled switching circuit;

a current sensing circuit (37) connected to the primary of the ignition coil (18) and sensing the intensity of current flow therethrough, and a spark duration circuit (38) sensing occurrence of a spark and connected to the secondary of the coil (18);

the voltage sensing circuit and the spark duration circuit being, respectively, connected to the control inputs of the controlled switching circuit (36), the output of the controlled switching circuit being connected to and controlling operation of said controlled switch (16) to cause said controlled switch to open, and close, in dependence on occurrence of the first one of said ignition signals and, subsequently, when the current through the ignition coil reaches a predetermined value.

4. System according to claim 1, further comprising a timing circuit (35) controlling the means (34, 36) generating the plurality of ignition pulses, the timing circuit determining the time duration during which the plurality of ignition pulses are provided;

and wherein the first one of said pulses is connected to said timing circuit to start the timing interval thereof.

5. System according to claim 1, wherein the means determining the timing of the event comprises an ignition signal marking transducer (10) coupled to the internal combustion engine and providing an output signal at a predetermined angular position of a piston within the engine, the angular position of the piston upon generation of the signal determining the operating time duration of the means (34, 36) generating the plurality of ignition pulses.

6. System according to claim 1, wherein (FIG. 4) the means generating the plurality of ignition pulses comprises a pulse transducer (10") having a plurality of closely spaced ignition pulse markers (100), coupled to the crankshaft of the engine (E) and providing a plurality of ignition pulse signals;

said ignition pulse signals being connected to the ignition pulse control stage (14);

and means (33") bypassing the ignition pulse control stage and applying said plurality of pulses directly to the control input of the controlled switch (16).

7. System according to claim 1, for combination with the internal combustion engine comprising circuit means (25; 33) having a control input;

means (21, 22, 26, 27, 31, 17) providing sensed output signals corresponding to a parameter of operation, or operating condition of the internal combustion engine;

presence of at least one of said parameter signals at the ignition instant of any one ignition event controlling said circuit means to, in turn, control said means to generate a plurality of ignition pulses to provide said plurality of ignition pulses to the controlled switch (16).

8. System according to claim 7, wherein (FIG. 4) the means generating the plurality of ignition pulses comprises a pulse transducer (10") having a plurality of closely spaced ignition pulse markers (100), coupled to the crankshaft of the engine (E) and providing a plurality of ignition pulse signals;

said ignition pulse signals being connected to the ignition pulse control stage (14);

means (33") bypassing the ignition pulse control stage and applying said plurality of pulses directly to the control input of the controlled switch (16);

and wherein the output of said circuit means (32) is connected to said bypass means (33) to enable bypassing the plurality of signals from the transducer (10") past the ignition pulse control stage directly to said controlled switch (16).

9. System according to claim 7, wherein the means determining the timing of the event comprises an ignition signal marking transducer (10) coupled to the internal combustion engine and providing an output signal at a predetermined angular position of a piston within the engine, the angular position of the piston upon generation of the signal determining the operating time duration of the means (34, 36) generating the plurality of ignition pulses;

and wherein the output of said circuit means (32, 33) is connected to control said means (34) generating the plurality of ignition pulses to provide pulses from said pulse generating means only if at least one of said parameters provides a corresponding signal to said circuit means (25, 33).

10. System according to claim 7, further comprising a timing circuit (35) controlling the means (34, 36) generating the plurality of ignition pulses, the timing circuit determining the time duration during which the plurality of ignition pulses are provided;

wherein the first one of said pulses is connected to said timing circuit to start the timing interval thereof;

and wherein the output of said circuit means (32, 33) is connected to control said means (34) generating the plurality of ignition pulses to provide pulses from said pulse generating means only if at least one of said parameters provides a corresponding signal to said circuit means (25, 33).

11. System according to claim 7, wherein one of the control inputs comprises the starting switch (26) of the starter motor for the engine (E).

12. System according to claim 7, wherein at least one of said control inputs includes a threshold stage (23, 24, 29, 30), a sensor, sensing a respective parameter being connected to sense said parameter and having its output applied to said threshold stage, the threshold stage providing, or not providing an output to the control input of the circuit means in dependence on the respective value of the sensed parameter.

13. System according to claim 7, wherein the sensed parameter comprises engine speed, and the system includes an engine speed sensor.

14. System according to claim 7, wherein the sensed parameter comprises engine acceleration and the system includes an engine speed sensor and a differentiator.

15. System according to claim 7, wherein the sensed parameter comprises engine induction pipe pressure change and the system includes a pressure sensor and a differentiator.

16. System according to claim 7, wherein the sensed parameter comprises engine temperature and the sensor comprises a temperature sensor.

17. System according to claim 7, wherein a battery is provided to furnish a source of electrical energy to the system;

and wherein the sensed parameter comprises battery voltage, and the system includes a connection from said battery to said control input and responsive to voltage level of the battery.

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